Towards the Growth of hBN on Ge/Si Substrates by CVD

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Hexagonal boron nitride is a promising 2D material for a range of applications, including as a protection layer for high-mobility graphene, deep-ultraviolet optoelectronics, solid-state thermal neutron detectors and tunnel-barriers in tunnel devices.[1-3] In the past decade, research has mostly focussed on CVD synthesis of hBN on transition metal substrates, which is now able to produce wafer-scale, single-crystal hBN monolayers.[4] However, for integration of hBN-based devices with Si technology, layer transfer is needed, which critically impacts process scalability. Additionally, 2D films grown on and transferred from metal substrates are contaminated with metal atoms at concentrations unacceptable for front-end-of-line device integration.[5] Direct growth of hBN thin films on CMOS-compatible substrates solves these problems, but has received relatively little research attention so far. In this work, we investigate the growth of hBN on epitaxial Ge(001)/Si substrates in the pressure range of 10^{-6} – 10^{-3} mbar at substrate temperatures of 900-980 °C using borazine as the precursor. Grown hBN films were characterized using X-ray photoelectron spectroscopy, atomic force microscopy, Raman spectroscopy and cross-section transmission electron microscopy (TEM). First results indicated growth of relatively thick and rough layers of boron nitride on Ge(001) surfaces at 10^{-3} mbar and 900 °C. Raman spectroscopy confirmed the presence of hBN with the characteristic hBN E_{2g} peak appearing at 1366 cm^{-1}, see Fig. 1a. The FWHM suggests a nanocrystalline structure with crystallite sizes of about 3 nm. This was confirmed by cross-section TEM, showing a 47 nm thick, amorphous BN film containing many randomly oriented hBN crystallites about 2-3 nm in size. Increasing the growth temperature to 980 °C and reducing the borazine flux both increased the crystalline quality of the hBN film and reduced the growth rate. TEM images (Fig. 1b) show a hBN film consisting of 5-12 well-aligned layers with an interlayer distance of 3.35 Å, which is in good agreement with the literature value of 3.33 Å. The full investigation will be presented in this study.

References

[1] C. R. Dean, A. F. Young, I. Meric et al., Nature nanotechnology 5, 10 (2010) 722
[2] K. Watanabe, T. Taniguchi, T. Niiyama et al., Nature Photon 3, 10 (2009) 591
[3] L. Britnell, R. V. Gorbachev, R. Jalil et al., Nano Lett. 12, 3 (2012) 1707
[4] T.-A. Chen, C.-P. Chuu, C.-C. Tseng et al., Nature 579, 7798 (2020) 219
[5] G. Lupina, J. Kitzmann, I. Costina et al., ACS nano 9, 5 (2016) 4776

Figures

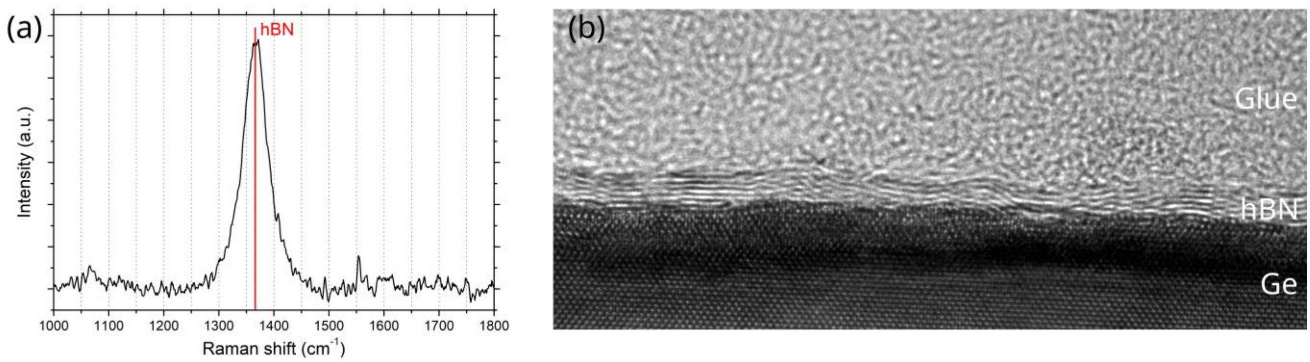

Figure 1: (a) Raman spectrum of hBN film grown on Ge(001), (b) cross-section TEM image.